Coastal Benthic Optical Properties
Fluorescence Imaging Laser Line Scan Sensor

Dr. Michael P. Strand
Naval Surface Warfare Center
Coastal Systems Station, Code R22
6703 West Highway 98, Panama City, FL 32407
phone: 850-235-5457 fax: 850-234-4867 email: strandmp@ncsc.navy.mil

Award #: N0001400WX21067

LONG TERM GOALS

Identification of mine-like contacts (MLCs) is a pressing fleet need. During MCM operations, sonar contacts are classified as mine-like if they are sufficiently similar to signatures of mines. Each contact classified as mine-like must be identified as a mine or not a mine. During MCM operations in littoral areas, tens or even hundreds of MLCs must be identified. This time consuming identification process is performed by EOD divers or ROVs, and is the rate limiting step in many MCM operations. A method to provide rapid visual identification of MLCs would dramatically speed up such operations. Acquisition of Electro-Optic Identification (EOID) sensors for MLC identification is currently underway to support both Air Mine Counter-Measures (AMCM) and Surface Mine Counter-Measures (SMCM) operations.

The scenario outlined above is viable in acoustically benign environments, but faces many obstacles in highly cluttered environments. Coral reefs are a prime example of an environment where current acoustic methods can be expected to have great difficulty. Our prototype Fluorescence Imaging Laser Line Scan (FILLS) sensor[1,2,3,4] has demonstrated that fluorescence imagery provides strong signatures which may be used to separate the coral clutter from mines. The image above demonstrates the ease with which a human observer can differentiate the mine like objects (MLOs) from the natural clutter in an environment that is difficult for sonars. Accordingly, this technology is a leading candidate for **extending MCM capabilities into highly cluttered environments**. In this role, FILLS imagery can be used for MLC detection, classification, and identification.

OBJECTIVES

The objective is to explore the exploitation of FILLS imagery to extend MCM capability into highly cluttered environments. This includes establishing a firm understanding of the elastic scatter and fluorescent scatter signatures of mines, clutter, and natural backgrounds, and exploring algorithmic approaches to exploit fluorescence to locate manmade objects, while rejecting coral clutter.

APPROACH

The test site selected for CoBOP is the Caribbean Marine Research Center (CMRC) on Lee Stocking Island (LSI), Bahamas. This site was selected because it provides research support facilities in environments compatible with the overall objectives of CoBOP. The environments available include

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2001		**00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE

Coastal Benthic Optical Properties Fluorescence Imaging Laser Line Scan Sensor

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Surface Warfare Center,,Coastal Systems Station, Code R22,6703 West Highway 98,,Panama City,,FL, 32407

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Identification of mine-like contacts (MLCs) is a pressing fleet need. During MCM operations, sonar contacts are classified as mine-like if they are sufficiently similar to signatures of mines. Each contact classified as mine-like must be identified as a mine or not a mine. During MCM operations in littoral areas, tens or even hundreds of MLCs must be identified. This time consuming identification process is performed by EOD divers or ROVs, and is the rate limiting step in many MCM operations. A method to provide rapid visual identification of MLCs would dramatically speed up such operations. Acquisition of Electro-Optic Identification (EOID) sensors for MLC identification is currently underway to support both Air Mine Counter-Measures (AMCM) and Surface Mine Counter-Measures (SMCM) operations.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

coral reefs, sediments, and sea grasses. Specific study sites in each of these environments were selected by CoBOP.

The primary sensor used by this project is the prototype FILLS sensor. This is supplemented with a Reson Seabat 6012 ahead looking sonar which is used for target reacquisition, and a down looking Seabat 9001 sonar, which provides swath bathymetry information.

For CoBOP-98 the FILLS sensor and the Seabat 9001 were deployed on the Harbor Branch Oceanographic Institute's (HBOI) Clelia minisubmarine. On this deployment platform it was possible to image the deeper water CoBOP environments. However, it was not possible to deploy in study sites shallower than about 50 feet. Moreover, accurate navigation information, such as that provided by differential global positioning system (DGPS), could not be obtained. This precluded useful FILLS surveys of areas other than study sites where divers installed transect lines.

For CoBOP-99 it was decided to install the FILLS sensor and the Seabats on a towed body in order to 1) enable FILLS imagery at shallower water CoBOP test sites, 2) provide accurate control of sensor altitude, and 3) merge accurate navigation information (DGPS) with the FILLS data stream. This change also enables deployment of the FILLS sensor at other sites where the Clelia cannot operate, including a 1999 deployment of FILLS at the derelict World War II minefield near Key West.

WORK COMPLETED

The FILLS sensor was deployed at the CoBOP LSI test site during the May 1998 field test[5,6]. FILLS imagery was obtained of coral reefs, sediments, sea grasses, and various other targets including mine-like objects. The FILLS and Seabat sensors were integrated into a CSS active depressor towed body for the 1999 and 2000 LSI field tests. This integration was fully successful, and FILLS imagery was successfully obtained of all the desired target environments (sediments, sea grasses, and coral reefs) and targets (MLOs and fluorescence panels) at North Perry, Rainbow Gardens, Adderly Cut, and Channel Marker.

In FY01 the attention was on the analysis of the data collected during prior years field activities. An ENVI-based data analysis tool was written for the display and quantitative analysis of the FILLS imagery. It reads raw FILLS data files, with no requirement for data preprocessing. Calibration information has been incorporated into the program, so that results can be displayed in digital counts (as recorded in the raw data files), photons, or photons per output (laser) photon. Log10 scaling of the imagery is available, for convenient display and analysis of the high dynamic range of the fluorescence imagery. The log10 scaled "photon per photon" images of a coral head shown in figure 1 give a good indication of the signal strength obtained in FILLS imagery. A similar ENVI analysis tool has been written for interpretation of the Seabat 9001 swath bathymetry files. Figure 1 also shows 1) the altitude (elevation) of the coral head above bottom and 2) the range from the sensor to the coral head. These tools will be used for quantitative analysis of the FILLS imagery.

In FY01 the attention was also focused on development of an algorithm to utilize the fluorescence information to highlight manmade objects in FILLS imagery, while rejecting the coral reef clutter in the imagery. The approach investigated exploits the fact that manmade objects mask the fluorescence signals from the underlying sediment, creating "holes" in the fluorescence signals. Locating the "holes" in the fluorescence images was done by calculating the mean and standard deviations of the

fluorescence returns from "sediment-like" regions of the image. Sediment-like regions were characterized by small local variations in the image for each of the four channels, while the coral regions are characterized by larger local variations in the return. A "local standard deviation" calculation was used to construct a mask to differentiate the coral-like and sediment-like regions of the image. This mask was used to compute statistical properties of the sediment portions of the image. The "holes" in the fluorescence image were identified by thresholding the fluorescence image returns as compared to the statistical properties of the sedimentary portions of the image. This procedure has been documented in a conference paper prepared for presentation at Oceans 2001.

In FY01 inputs were made for the paper "Multispectral fluorescence laser line scan imaging of coral reefs", submitted to "Limnology and Oceanography" by Charles H. Mazel, Michael P. Strand, Michael P. Lesser, Michael P. Crosby, Bryan Coles, and Andrew J. Nevis.

Also in FY01 inputs were made for the paper "Underwater Optical Imaging: Status and Prospects", by Jules. S. Jaffe, John McLean, Michael P. Strand, and Karl D. Moore, and published in the September 2001 issue of Oceanography[7].

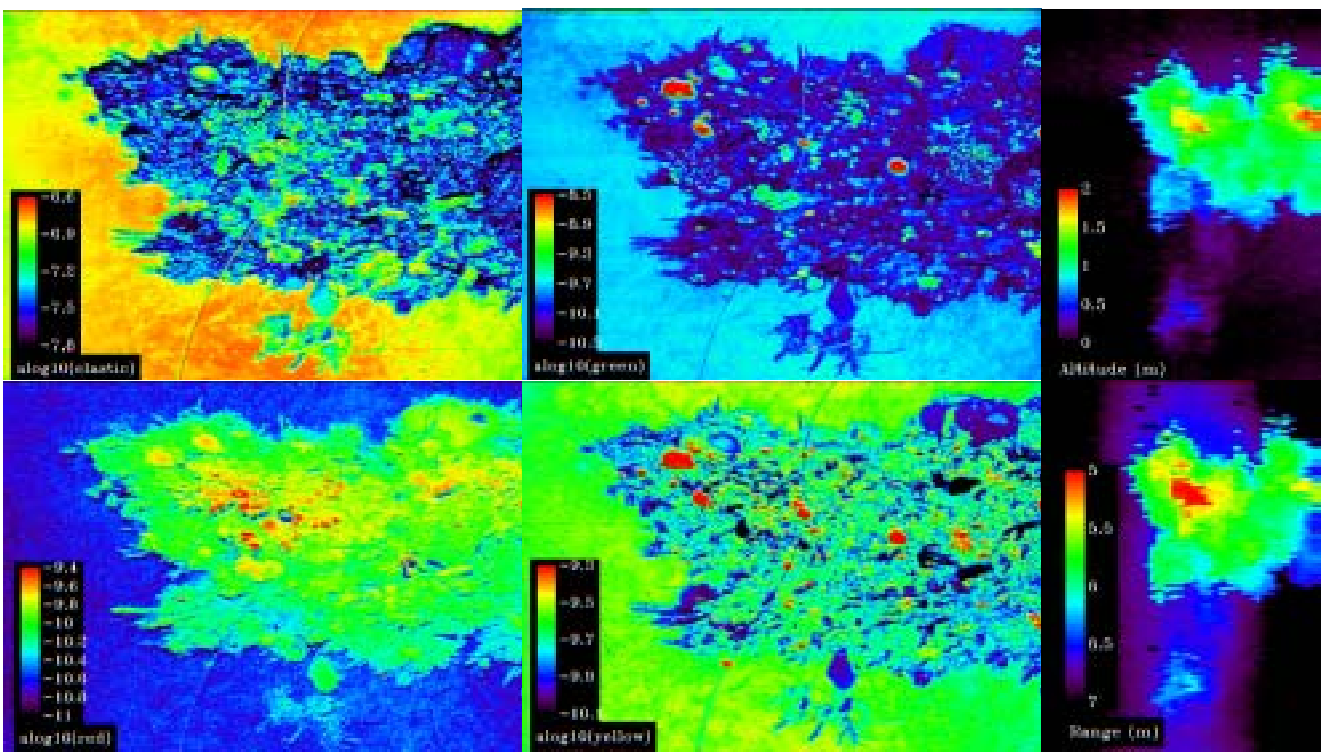

Fig. 1. The left 4 subimages are log10 images of the signal return in the 4 channels of the FILLS sensor, on a photon detected per laser photon transmitted basis. The right 2 subimages show the altitude of the coral head above the bottom, and the range from the sensor to the coral head.

RESULTS

It has been clearly demonstrated that the type of sediment strongly influences the background fluorescence signal. The masking of the fluorescence from the sediment is what is exploited by the algorithmic approach pursued in FY01 for highlighting manmade objects while rejecting clutter from the coral reef. Figure 2 shows the images from each of the four channels, as well as a pseudo-color image formed from the fluorescence channel imagery. Figure 3 shows the background masks formed from the local standard deviation of the each of the four channels, as well as a composite mask formed by OR-ing the masks from the four individual channels. It is evident that this composite mask separates most of the coral (and some of the manmade objects) from the sediment. This mask is used to compute the statistical properties of the sediment, for use in thresholding to fine the "holes" in the fluorescence signals, indicating manmade objects. Figure 4a-b show the object masks formed by thresholding the red and yellow fluorescence channel images, respectively. Figure 4c shows the composite object mask formed by ANDing the red and yellow masks. Figure 4d shows the final object mask, formed by cleaning up the 4c mask using standard mathematical morphology operations. This final mask selects the manmade objects, while rejecting the extensive coral clutter.

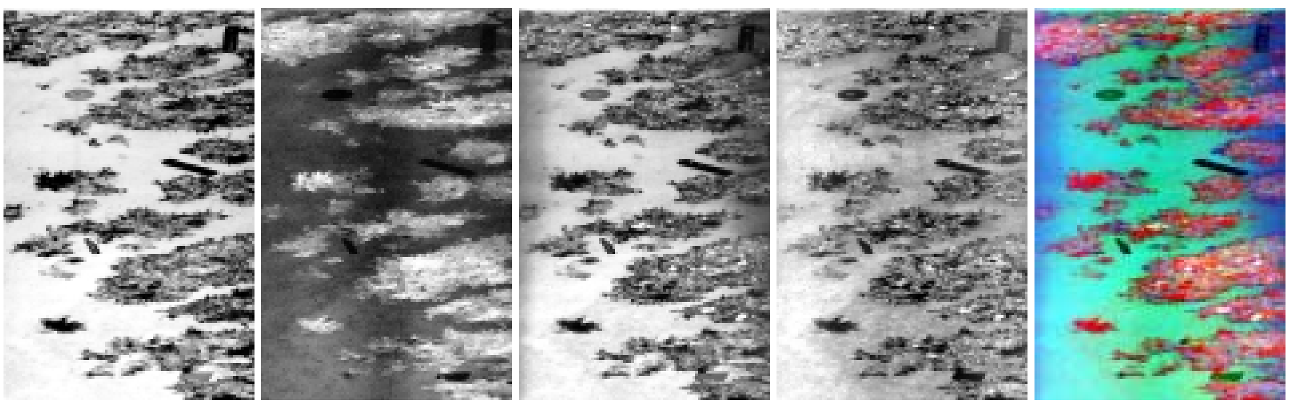

Fig. 2. The images produced by the a) elastic scatter channel, b) red fluorescence channel, c) green fluorescence channel, and d) yellow fluorescence channel. e) shows the pseudocolor image produced by mapping the red, green, and yellow channel images to RGB, respectively.

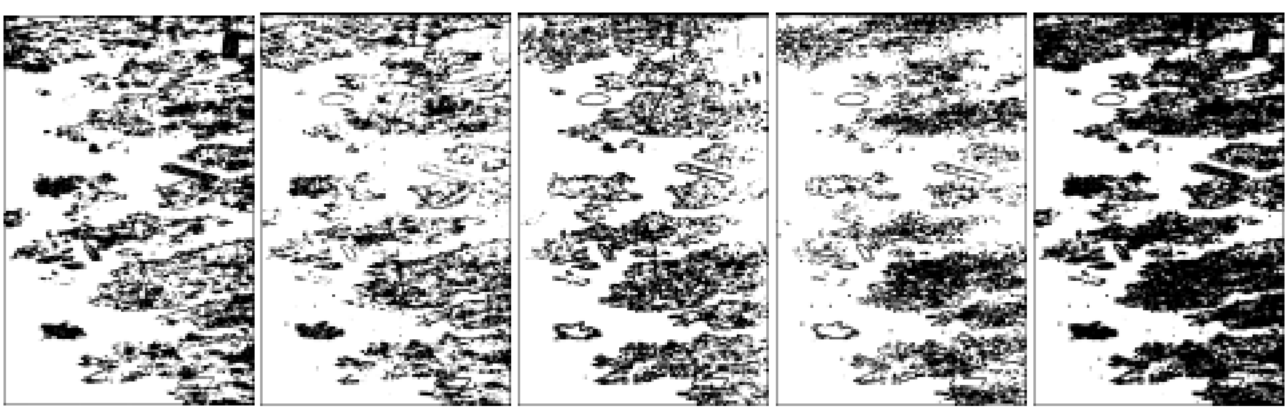

Fig. 3. The Local Standard Deviation (LSD) background masks formed from the elastic, red, green, and yellow images are shown in subfigures a-d), respectively. Subfigure e) shows the composite LSD background mask formed by OR-ing the LSD background masks form the 4 channels.

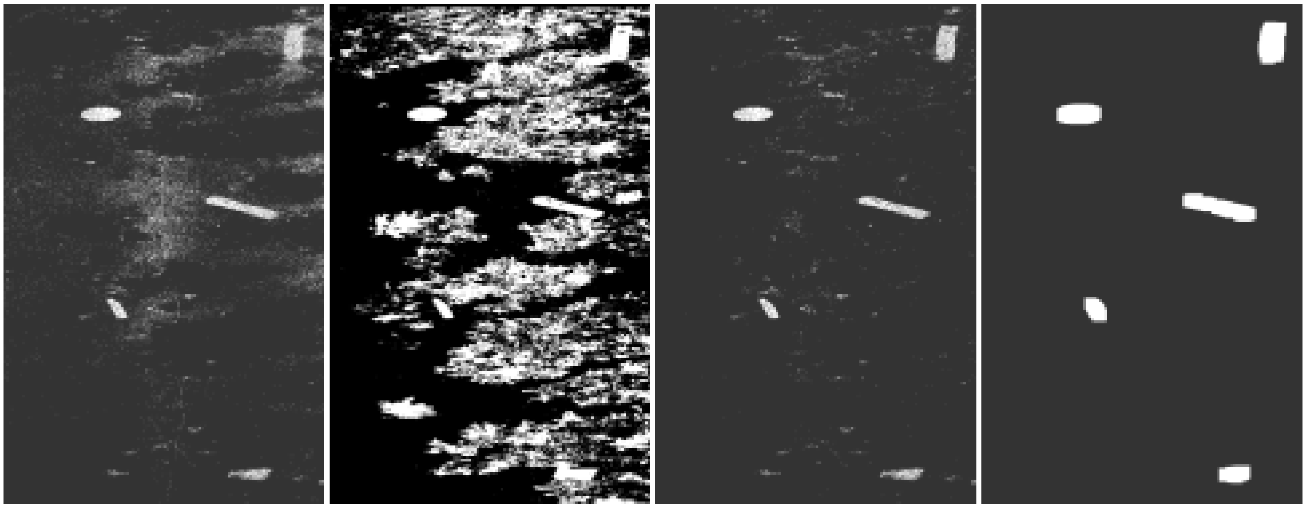

Fig. 4. a) and b) show the background masks formed by thresholding the red and yellow channel images, respectively. c) shows the AND-ing of masks a) and b). d) shows the final object mask formed by cleaning-up mask c) using standard mathematical morphology operations. This final mask selects the manmade objects, while rejecting the extensive coral clutter.

IMPACT/APPLICATIONS

Results obtained by this and related CoBOP projects are expected to play a key role in the decisions of what technology to pursue for the next generation Advanced Electro-Optic Identification Sensor.

TRANSITIONS

This work is one of the ONR sponsored projects that have lead to the transition of EOID sensors to the fleet to support both AMCM and SMCM.

RELATED PROJECTS

This project is closely coordinated with the Coastal Benthic Optical Properties (CoBOP) DRI. This project is studying the optical signatures of backgrounds, clutter, and targets. These signatures are key to the development of the automatic target detection algorithms required to support AMCM and SMCM.

REFERENCES

1. Strand, M.P., B.W. Coles, A.J. Nevis, and R Regan 1996: Laser Line Scan Fluorescence and Multi-Spectral Imaging of Coral Reef Environments, SPIE Vol. 2963, pp 790-795.

2. Nevis, A.J., and M.P. Strand 1997: Imaging Laser Polarimeter (ILP) Test Report, CSS/TR-97/33.

3. Nevis, A.J., J.S. Taylor, and M.P. Strand 1997: Massachusetts Bay Survey NON-MCM Test Report, CSS/TR-97/31

4. Nevis, A.J., J.S. Taylor, and M.P. Strand 1997: Massachusetts Bay Survey MCM Test Report, CSS/TR-97/32

5. Nevis, A.J., and M.P. Strand 1998: Multiple Channel Laser Line Scan FY98 Lee Stocking Island Test Plan, CSS/TN-98/28.

6. Nevis, A. J., and M. P. Strand 1998: Multiple Channel Laser Line Scan FY98 Lee Stocking Island Test Report, CSS/TR-98/29

7. Jaffe, J. S., J. McLean, M. P. Strand, and K. D. Moore 2001: Underwater Optical Imaging: Status and Prospects, Oceanography Vol 14, No 3, pp 65-75.